Emperor Penguins: Dive Masters of Antarctica

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Physiological responses during diving are distinct from those found in exercising terrestrial animals (See Table 1). Although these responses are graded during dives, their combined effects regulate the management of O_2 stores, serve to decrease rates of O_2 depletion, and prolong the durations of dives.

To resolve differences in heart rate and O_2 store management between deep (>200 m) and shallow (<200 m) dives of emperor penguins, we deployed digital electrocardiogram recorders on foraging birds from the Cape Washington emperor penguin colony.

In general, heart rate profiles during dives revealed that high surface heart rates of >200 beats per minute (bpm) declined abruptly to approximately 100 bpm at the start of the dive, and then, decreased gradually to below resting values (~65 bpm, see Figure 1 and 1a). Heart rate slowly increased during ascent and immediately returned to the initial high values at the surface.

In shallow dives, the lowest heart rates were near resting values (i.e., ~65 bpm). However, in deep dives, heart rate was as low as 10 bpm during much of the central portion of the dive.

Moderate heart rates during shallow dives and during the shallow segments of deep dives support continued gas exchange with the lungs. However, during deep dives, heart rates below 10 bpm minimize gas exchange, and conserve lung O_2 for later use during the ascent. In addition, this dramatic reduction in heart rate and gas exchange slows the transfer of lung nitrogen to the blood, and thus, decreases the risk of decompression sickness during these deep dives.

In the same manner, the moderate heart rates seen at shallow depths may allow for some muscle blood flow, but during the deepest segments of extreme dives, the very low heart rates observed should result in widespread, intense vasoconstriction and no muscle blood flow. During these very low heart rates, muscle would be entirely dependent upon its myoglobin-bound O_2 for aerobic metabolism.

Unlike exercising terrestrial animals, diving emperor penguin decrease heart rate both to manage O_2 depletion and to avoid the complications from diving to great depth.

Table 1: **A Comparison of Physiological Responses Between Terrestrial Exercise and Diving**

	Heart Rate	Lung Gas Exchange	Muscle Perfusion	O_2 Consumption
Terrestrial Exercise	↑	↑	↑	↑
Diving	↓	↓	↓	↓

Figure 1: **Heart Rate and Depth Profiles at Sea.**

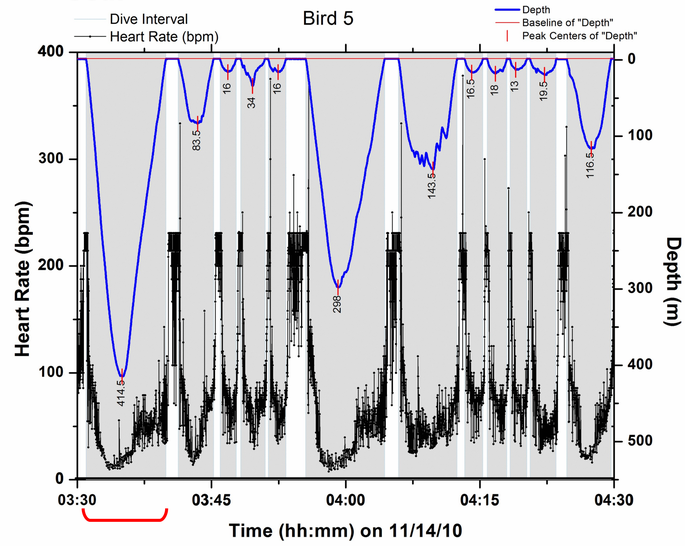

Figure 1a: **Detail of Heart Rate and Depth Profiles at Sea – 415 m Dive.**